Hydrographic measurements in Jökulsárlón lagoon, Iceland

Conference or Workshop Item

Hydrographic measurements in Jökulsárlón lagoon, Iceland

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The Open University

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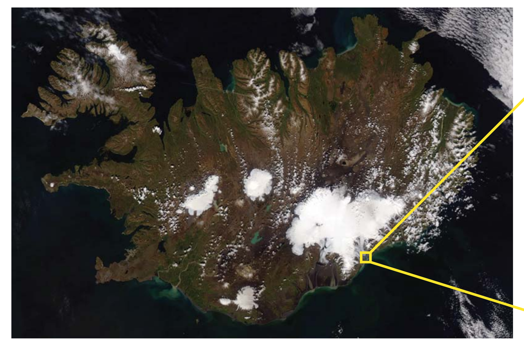
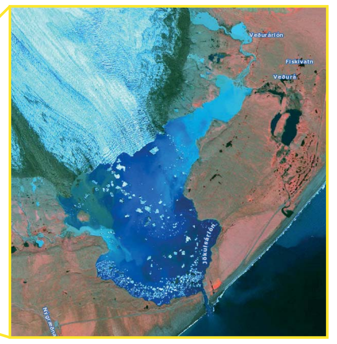
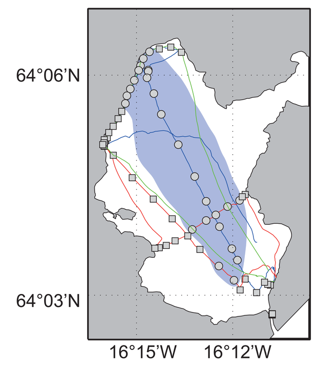
1 Jökulsárlón lagoon is an enclosed lake bordering the Breiðamerkurjökull glacier



Aqua/MODIS satellite image of Iceland captured on 20 July 2008. The yellow box encloses Jökulsárlón lagoon.



False colour image of Jökulsárlón lagoon, Iceland. Breidamerkurjökull glacier is at the top of the picture and grounded icebergs are clear



CTD survey of the lagoon. Squares are CTD stations which sampled to the lake bed. Circles did not. The blue shaded region represents water >100m depth. Blue is the track on day 1, red day 2, green day 3.

Jökulsárlón lagoon is a proglacial lake on the south west coast of Iceland. It borders the retreating Breidamerkurjökull glacier which flows down from the Vatnajökull ice cap and discharges into the lake at a rate of ~260 x $10^6 m^{-3}$ yr (Björnsson et al., 2001). The lake is connected to the North Atlantic through a narrow channel only ~80 m wide and ~6 m deep, and all tidal and residual flows in and out of the lake are through this channel.

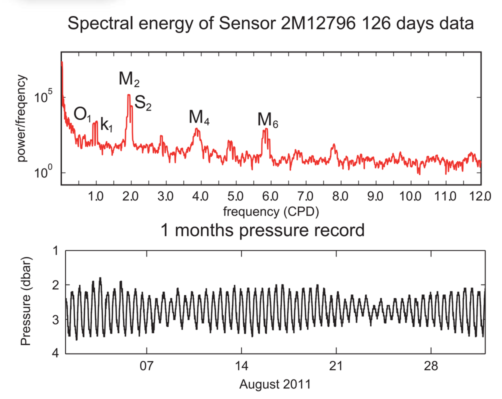
The lagoon was formed in the 1930's as the glacier retreated, and since formation, the surface area has increased linearly from ~5km^2 in 1960, to ~15 km^2 in 1999. It currently measures just over 23 km^2. The bed beneath the Breidamerkurjökull glacier has a reverse slope and the the lake is expected to continue to increase in size as the glacier continues its retreat (Björnsson et al., 2001).

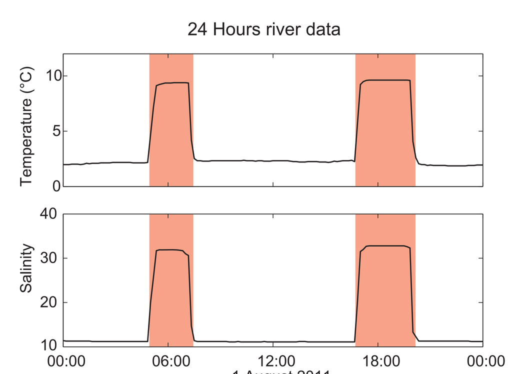
Hydrographic work in the 1970's showed the deepest regions of the lake (>100 m) had salinities of only ~4-5 (Harris, 1976), and that there was no consistent tidal connection between the lake and the Ocean. For large parts of the year saline water was not able to enter the lake. Since 1976 the lake has increased in size by a further ~15 km^2.

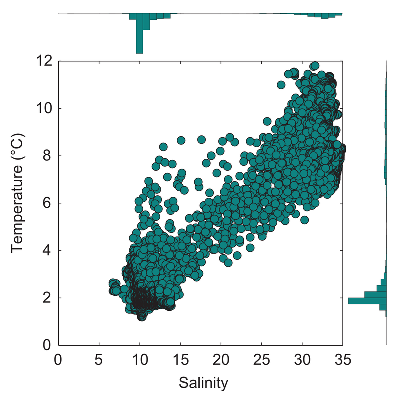
Energy balance studies of the lake (Landl et al., 2003 and Björnsson et al. ,2001) have demonstrated the importance of the heat from the ocean in the decay of the calved ice. However in the absence of modern hydrographic data from the lagoon these studies have used data from Harris (1976) for their calculations.

In April 2012 we conducted four hydrographic sections to determine the early season hydrographic structure of the Jökulsárlón lagoon.

2 The inflow to the lagoon is in discrete pulses



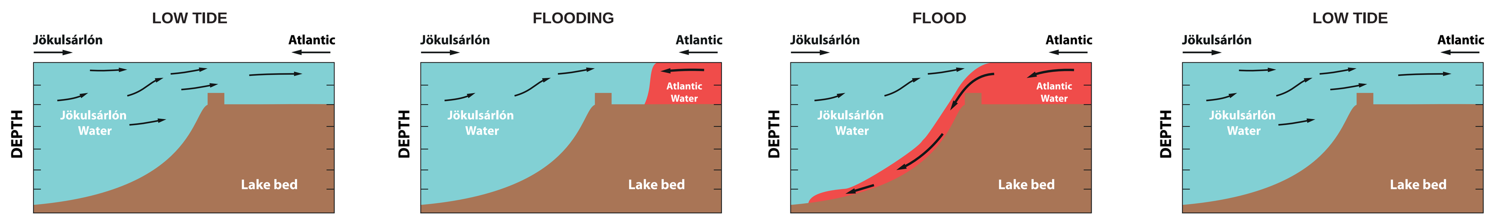




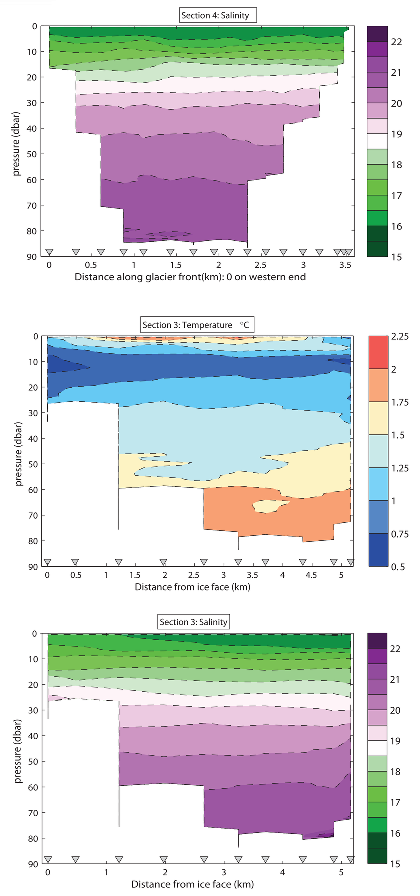
Four sensors deployed in the connecting channel for four months recording pressure, temperature and salinity reveal the inflow to the lagoon.

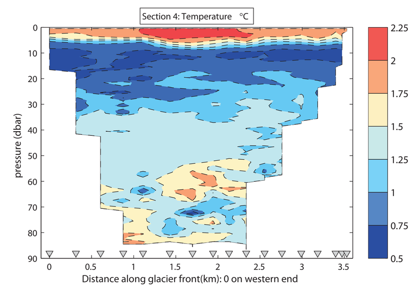
Harris (1976) observed that there was no consistent tidal connection between the lake and the Atlantic Ocean, and that for large parts of the year saline water was not able to enter the lake.

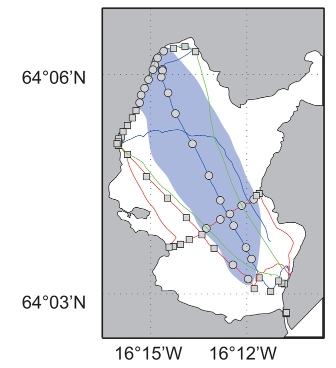
The data here show that saline water enters the lagoon every day.



3 The synoptic CTD Stations show the hydrographic structure across the lagoon

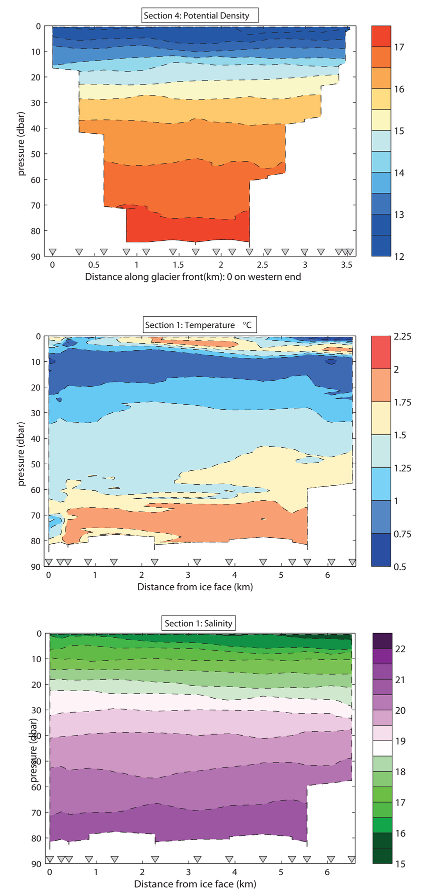




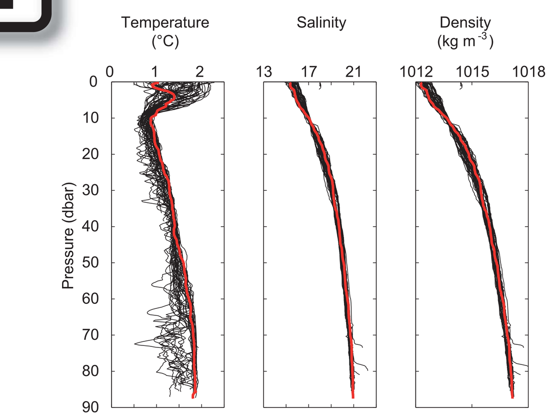


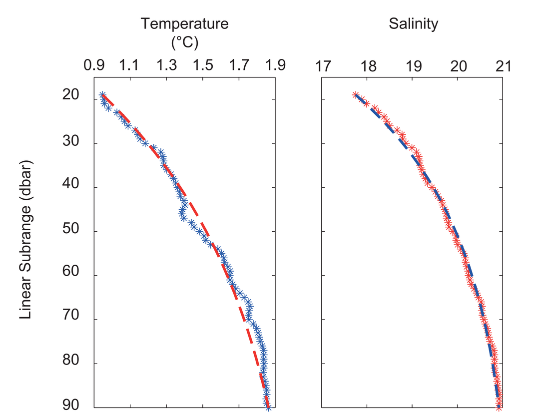
In April 2012 four hydrographic sections show warm saline water at the lake bed, and reaching the ice face.

The lake has significantly changed.



4 Away from the ice face advection-diffusion dominates





The stars in the plots above are the region where advection / diffusion processes dominate away from the ice face. The dashed lines are my modelled temperature and salinity based on the calculated z*.

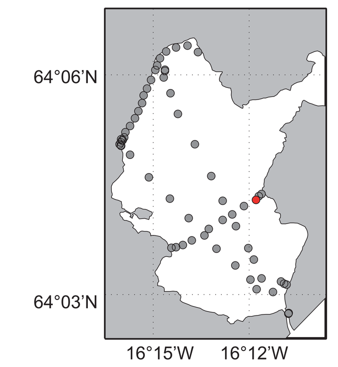
The three panels on the left show the vertical profiles for the whole data set.

Regions with significant structure are close to the ice face. Away from the ice face the vertical structure is relatively smooth.

The location of the profile highlighted in red on the left is shown in the map on the right.

With a constant supply of warm saline water, from the tidal inflow advecting into the basin, the heat and salt diffuse upwards.

This system can be modelled simply with a 1-dimensional advection-diffusion equation.



$$k_z \frac{\partial^2 C}{\partial z^2} = w \frac{\partial C}{\partial z}$$

$$c = a_1 + a_2 e^{\frac{z}{z^*}}$$

$$z^* = \frac{k_z}{w}$$

$$z^* = 38.7 \pm 1.63\ m$$

k_z is the vertical turbulent diffusivity.

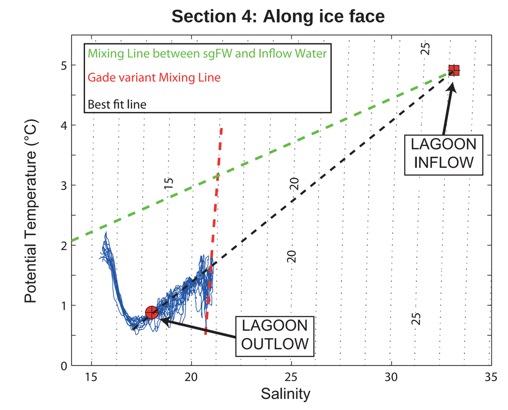
w is the vertical velocity.

z^* is a scale height.

For a typical k_z, the vertical velocity is ~0.2 m per day or ~80 m per year.

This is a constant source of hear to melt the ice in the lagoon, and the glacier front.

5 Close to Breiðamerkurjökull glacier the contribution from melting ice is clear.



The θ / S structure of the water column is determined by the interaction of the three sources: inflow to the lagoon, the melting of ice, and sub glacial fresh water.

By considering the conservation of heat and salt in a volume of water close to the ice, we can derive equations for the gradient of a line in θ / S space as.

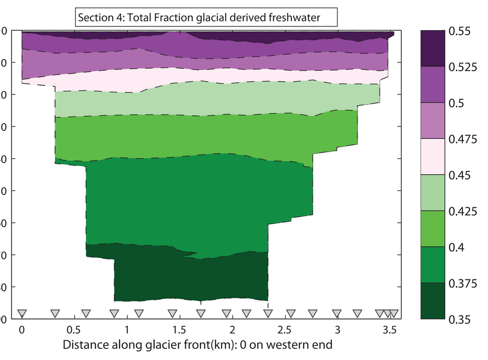
$$\frac{\partial T}{\partial s} = \frac{1}{S}\left(\frac{L}{c_p} - \frac{c_i}{c_p}\left(T_i - T_f\right) - \left(T_f - T\right)\right)$$

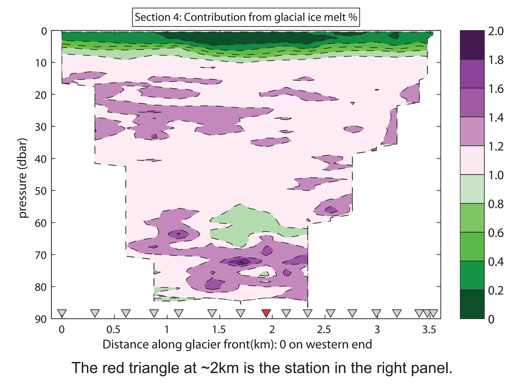
T is the temperature, S the salinity, ci and cp the specific heat capacities of ice and water, Ti the temperature of ice, and Tf the freezing temperature.

This gives a so-called Gade melting line after Gade (1979), which was refined by Jenkins(1999) and most recently by Mortensen et al (2013).

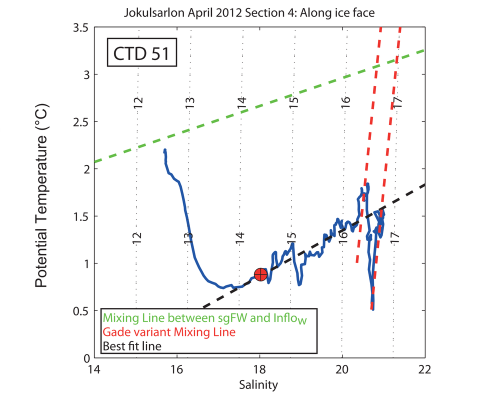
The panel on the lower right clearly shows that in the more saline deep water, the profiles follow a Gade line.

Using this we can derive the contribution of glacial melt to the along ice face measurements.

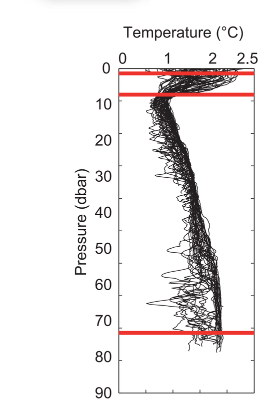


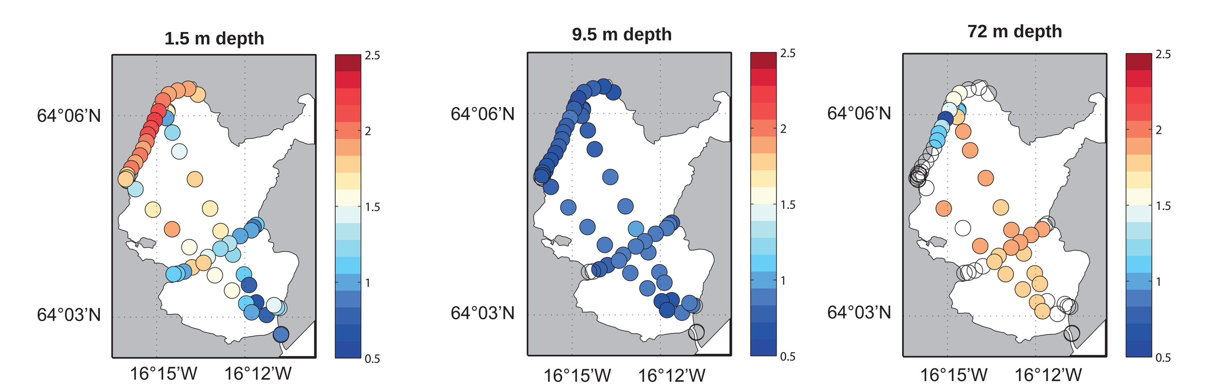


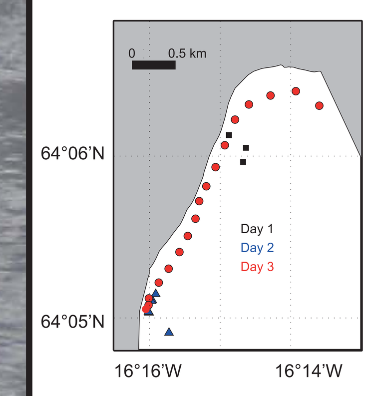
The red triangle at ~2km is the station in the right panel.



6 The warmest and coldest water in Jökulsárlón lagoon were adjacent to the Breiðamerkurjökull glacier



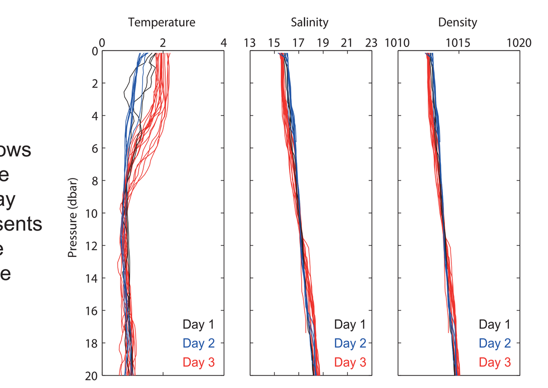




Plotting the data at depth levels reveals that surprisingly the warmest water sampled in the lagoon was in the very near surface and adjacent to the ice face. By 9.5 m the signature of this warm water had gone.

We visited the ice face over three days. The map on the left shows the location of stations sampled, and the profiles on the right the stations. The excess heat on day 3 is ~0.8°C higher than on day 1. Assuming a solar insolation of 200 Wm-2 the warming represents ~7 hours solar input, and so solar heating is likely. Note that the warmest water is in the centre of the face. This implies a surface circulation pattern.

At 72m the coldest water sampled is also at the ice face.



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